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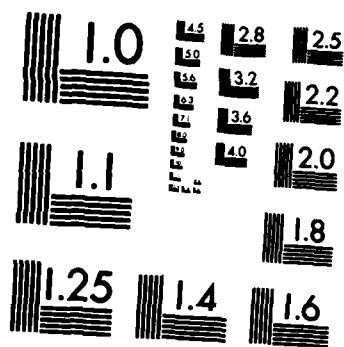
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SYSTEM FOR LASER SPOT PROFILE ANALYSIS

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and
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May 1983

Interim Report, October 1981-September 1982

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A system for laser spot profile analysis has been developed and tested, and field test experiments proposed for the evaluation of laser designator performance. Silicon television tube cameras are used to determine the OTF of the atmosphere and to view the laser designator spot. Fourier transform computer techniques are then used to separate the effects of the atmosphere from the effects of laser instability and platform motion.	

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A

SECTION 1. SUMMARY

1.1 Background

The spot patterns produced by laser designators suffer from a number of defects. The patterns are broadened, and exhibit wander and intensity fluctuation, because of turbulence in the atmosphere. Designator spot patterns also exhibit similar defects because of internal laser instability and motion of the transmitter platform. In order to correct the latter defects, a system is needed that is capable of separating the contributions of the several effects.

Previous work at the Naval Postgraduate School (1,2,3) and elsewhere (4), has demonstrated that the effects of atmospheric turbulence on designator spot patterns can be expressed in terms of the OTF (Optical Transfer Function) of the atmosphere. This quantity is the Fourier transform of the spot profile due to the atmosphere alone. If other causes of spot broadening are present, such as laser instability and platform motion, the spot profile will be the convolution of the spot profiles due to each of the effects. The spot profile broadening due to laser and platform instability can then be separated from the atmospheric effects by dividing the Fourier transform of the spot profile by the OTF of the atmosphere (point by point as a function of spatial frequency). The necessary OTF of the atmosphere can be obtained by means of a slit-scanning telescope system, which views a point laser in the target vicinity from a location near the designator transmitter. An additional imaging system, viewing the designator spot on a target screen, from a location near the target, yields the composite spot profile. Data from this imager, together with that from the telescope imager at the transmitter site, can separate the various effects. As will be described later in more detail, spot motion and spot broadening are separated by computer tracking (image centering) techniques, applied to the data from the spot profile TV camera.

Because designator lasers use short pulses, the previously developed mechanical slit-scan techniques cannot be used. Storage imaging systems, using TV, CCD, or CID techniques, are needed to sense the image for the very short pulse periods, and provide the equivalent of a slit-scan during the interpulse period. TV was chosen over CCD or CID techniques for this purpose, because of higher interpixel uniformity for TV.

1.2 Objectives

The principal objective of the work described in this report was to demonstrate the quantitative separation of the relative contribution of the effects of atmospheric turbulence, laser instability, and platform motion, by utilization of TV imaging systems. The basic principles of this separation have been established by previous work at the Naval Postgraduate School, in

terms of Fourier transform data processing. However, the previous experimental work there has been carried out with mechanical slit-scanning optics. A principal objective was thus the verification that television imaging systems can yield the same results as slit scanning systems. The techniques were to be tested in the laboratory, but be capable of implementation in the field. The relevant field conditions to which this should apply are to include the use of a uniform reflectivity target for the designator spot. However, the techniques should also be adaptable to the case of a realistic nonuniform reflectivity field target, such as a tank. Also, although not part of the required objective, the techniques employed were to be chosen, where possible, to be extendable later to the use of moving targets. An additional objective of the work was to verify the effectiveness of the equipment chosen for the experimental program.

1.3 Summary of Procedures

Techniques were developed and tested in a 135 m. long medium-turbulence optical tunnel, for the purpose of obtaining the Modulation Transfer Function (MTF), and C_n^2 (a measure of the severity of turbulence) for the path, by means of a television imaging system. The system imaged a point laser source at the far end of the tunnel, simulating a laser mounted in the designator target during field tests. The television signals were recorded on analog tape, then digitized and processed later. The recording techniques were tested and found to be sufficiently linear. A computer data processing system developed for the TV data reduction was tested on the observed TV image signals.

A previously proven slit-scan system for measuring MTF and C_n^2 and the TV imaging system described above, were then used simultaneously to view identical images of a point laser source at a distance. The images were obtained by means of a half transmitting mirror splitter in the telescope output. The signals for both systems were recorded and data-processed by Fourier transform techniques to yield values of the turbulence structure constant, C_n^2 as a quantitative means of comparing the results obtained by the two systems. The results are summarized below.

The procedures for digital subtraction of residual background (persisting through the laser line filter), in TV images of the laser spot pattern on a uniform screen, were tested, using a Quantex DS-30 digital image processor. The data processing to yield the MTF from the resulting background-free laser designator spot was then tested.

Extension of the techniques, to the case of laser designator targets with nonuniform reflectivity, was analyzed in principle, and found to be practical. Actual performance testing of this process awaits the availability of a larger computer planned for future acquisition at Ft. Huachuca.

1.4 SUMMARY OF RESULTS

Measurements of the OTF of the atmosphere made by means of TV imaging systems are in agreement with measurements made through identically the same atmosphere with mechanical line scanning equipment. Also, tests of the recording systems needed for proposed field test measurements show that the recording equipment is sufficiently linear to permit data reduction to be carried out later. The general techniques are capable of separating the effects of atmospheric turbulence, internal laser designator instability, and effects of platform motion.

1.5 ANALYSIS

The laboratory tests indicate that the field tests should perform as planned.

1.6 CONCLUSIONS

The proposed field experiments to separate the effects on laser designators of atmospheric turbulence, internal laser designator instability, and platform motion can be successfully carried out with the techniques and equipment recommended.

1.7 RECOMMENDATIONS

It is recommended that the proposed field test experiments be carried out to separate the effects of turbulence, internal laser instability, and platform motion in laser designators.

SECTION 2. DETAILS OF INVESTIGATION

2.1 Introduction

The experimental and analytical program carried out has been that necessary to establish the validity of experiments proposed for a later field test program. That test program is summarized in section 3.A. Briefly, the proposed field test program addresses the problem of separating the types of instability in laser designators, i.e. turbulence, the internal stability of the laser designator and its optics, and the platform instability.

The effects of atmospheric turbulence are broadening of the image profile, wander of the center of the beam and scintillation within the beam profile. The scintillation is the most difficult to handle in detail. However it can be circumvented by dealing with the profile as observed in the average of a number of individual pulse profiles.

The effects of turbulence on beam propagation have been investigated at a number of laboratories, with perhaps the longest and most complete sustained program being at the Naval Postgraduate School.(1) This work has led to a well-verified analytical model for the beam profile to be expected after a beam

has traversed an optical path through the atmosphere. This is expressed in terms of the OTF or Optical Transfer Function of the atmosphere. Two forms of this are equally useful. One expresses the OTF for the average of a number of beam profiles without centering (or tracking) the beam. The other applies to a beam that is centered (or tracked) before averaging a number of profile measurements. In the course of centering before averaging, a tally of the offsets required gives the variance of the beam "wander". Both these quantities are functions of the turbulence constant for optical index, C_n^2 and the range, as well as the wavelength.

The beam spread resulting from a number of causes, such as the turbulence, designator instability, and platform instability, is the convolution of the profiles from each cause. This allows the Fourier transform convolution theorem to be utilized. This says that the transform of the convolution of several functions is the product of the Fourier transforms of those functions. This can be reversed and the functions unfolded by dividing the transforms point by point. This technique has been used to separate the types of broadening.

For the case of wander, where the statistical behavior is Gaussian, the variance of the displacement is the sum of the variances of the two component wanders. This allows separation of the wander terms.

2.2 Theoretical Background

Separation of the atmospheric contribution to the beam wander and broadening involves measuring the turbulence structure constant for optical index, C_n^2 . This can be determined in a number of ways. For example, it can be determined by measuring the temperature at points along the optical path. Although, in principle, it could be measured with thermal sensors, this has not been very practical in most instances. One difficulty is that the optical properties of interest here, the broadening and wander, depend on the integrated value of C_n^2 along the optical path. The relative importance of C_n^2 also varies with the position along the path, and this weighting factor depends on the particular type of optical property involved. The relative path-position weighting of C_n^2 is shown in Figure 1, for several different optical situations. The situation for an optical beam formed by a projector lens system is shown in 1a, for the case where the lens system is on the left and the target on the right. By a reciprocity theorem, a telescope system behaves in the same way as the projector, as shown in 1b, if the telescope is on the left and a point source is on the right. Other methods of measuring C_n^2 , for example, by scintillation, have different weighting. The case of scintillation is shown in Figure 1c. In this case, then, use of a telescope to measure C_n^2 will lead to the weighting needed to predict the behavior of the designator.

Use of scintillation as a means of measuring C_n^2 leads to a path-position weighting distribution as shown in Figure 1d. This emphasizes the center of the path and does not give the proper distribution to predict the behavior of a laser designator.

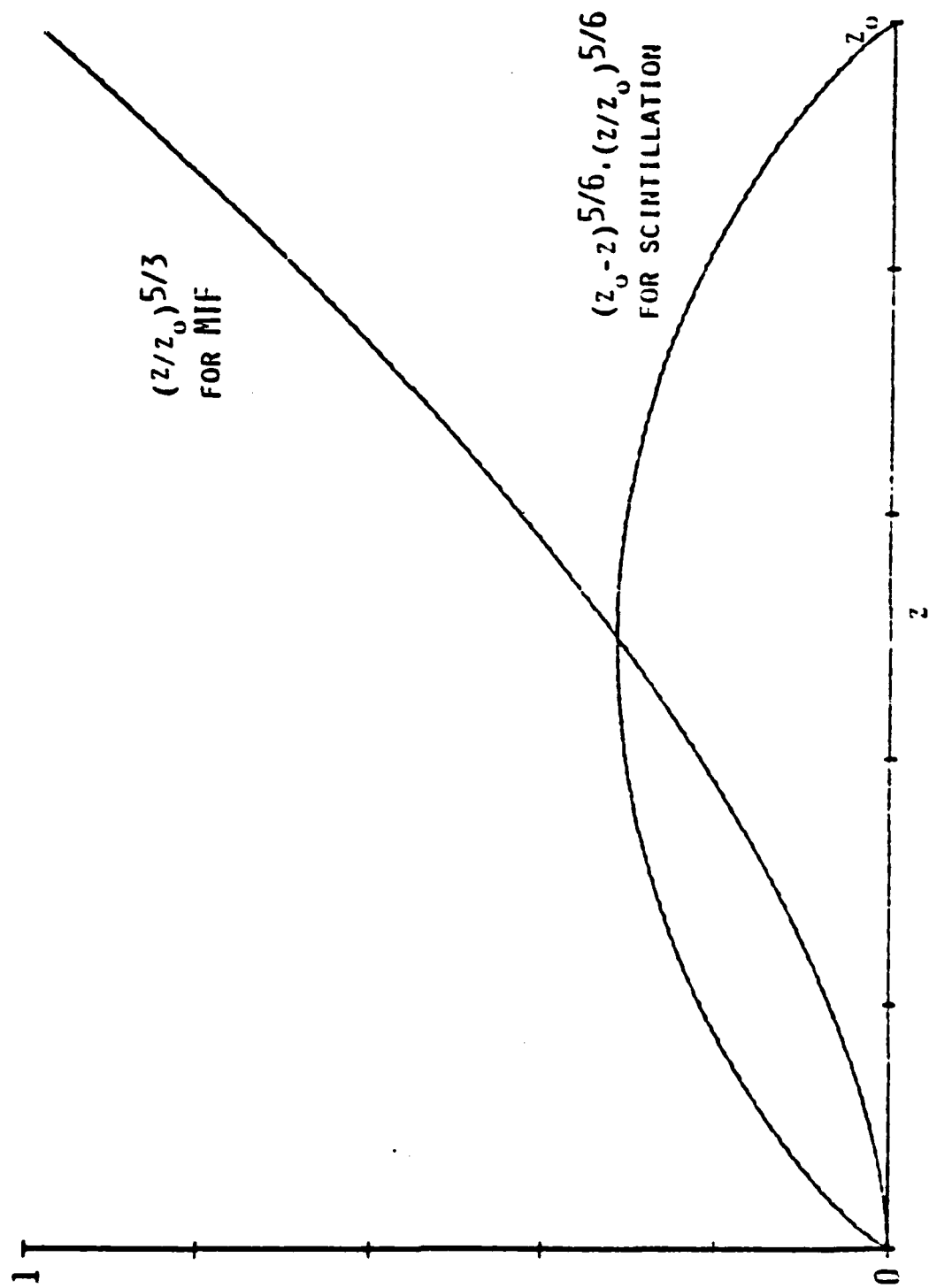


FIG. 1 RELATIVE WEIGHTING OF C_u^2 AS A FUNCTION OF POSITION ALONG THE PATH, FOR MIF AND FOR SCINTILLATION. THE TELESCOPE END OF THE PATH IS AT THE RIGHT.

2.3 EXPERIMENTAL PROGRAM

The experimental program to verify the practicality of the proposed field test program involved several facets. The general objective was verification of the general applicability of the use of TV imagers in place of mechanical line slit scanners for the purpose of separating the types of spot instability. This also involved the verification of the suitability and linearity of individual components of the proposed overall test system. We will look first at the tests of system components, followed by an experimental comparison of TV and mechanical line scanner techniques.

2.3a SYSTEM COMPONENTS

Silicon Vidicon

A silicon focal plane screen is needed for the vidicon in order to reach the 1.06 micrometer, near-IR, wavelength. The usual TV vidicons, or other TV cameras such as orthicons, are optimized for the visual range of wavelengths and do not reach this wavelength. A TV technique is needed because the pulse length of the designator is too short (a few nanoseconds) for a slit scanning system to function. The image of the designator spot is stored on the semiconducting sensitive surface of the vidicon. The electron beam raster scan interrogates the image to produce the usual composite TV video format. It was found on trial that each of the two interlaced "fields" of the raster completely reset the sensitive surface. The storage time is thus the 1/60 second between field scans. A test of the performance of the vidicon was carried out in the laboratory by imaging a broad spot produced by a GaAs laser at a wavelength of 0.905 micrometers.

Vidicon for Atmospheric OTF Measurement

A second vidicon is used to view a point laser source located in the target screen, in order to provide the data concerning the atmospheric OTF. (See Fig. 4, section 3.A.2.) This system is less demanding as far as pulse length is concerned, and the wavelength can be any value available in a convenient small laser, as long as it differs from the 1.06 micrometers of the designator. In practice a HeNe laser was used, emitting .6328 micrometers. A power of 1-3 milliwatts is sufficient. The viewing vidicon has a narrow band interference filter in its optical train to reduce the background signal and exclude the designator wavelength. In order to have sufficient magnification to resolve the spread of the image due to the atmospheric turbulence, this vidicon viewed the source through a 6 inch diameter cassegrain telescope, with a 90 inch focal length. This proved to be too low a magnification so a "Barlow" negative lens was inserted just ahead of the vidicon to increase the magnification by a factor of 3. This caused the typical image to occupy a width of the order of 10 pixels, sufficient to analyze the image.

Video Tape Recording

The vidicon signal is continuously recorded on a Panasonic, U-Vision, type NV9240 TV tape recorder system. One matter of immediate concern is whether the tape recorder is sufficiently linear to be used for data recording. Not only must a linear analog recorder be used in the field, but it is necessary to later identify and play back with precise identification, several individual fields. This requires a disc recorder with field and frame labeling. For this purpose an Eigen, model 16-10, Video disc recorder was used.

To test the linearity of the complete chain of amplifiers and two recording systems, images of a point source, broadened by the atmosphere were compared. Two types of signals are illustrated in Figure 2. 2(a) shows a single TV line that passes through the center of the recorded spot. The upper trace is direct from the TV. The lower trace is after the complete amplifier chain and two recording systems. The patterns are sufficiently alike to give comparable shape parameter measurements. In Figure 2b, a number of successive TV lines passing through the image are displayed. Again the top figure is direct and the lower figure is after the complete amplifier chain. The reproducibility is excellent.

Background Subtraction

Although both vidicon systems have narrow-band filters to reduce background light, it is not completely eliminated. In order to remove this, the signals are digitized in a Quantex DS-30 TV frame digitizer. This system can subtract the signals of one field from that of another. This is carried out, using the field recorded signals, to obtain the image signals of the designator and OTF vidicons alone.

Data Processing for Atmospheric C_n^2

In order to carry out a calculation of the atmospheric C_n^2 from an image of a point source at a distance, the OTF of the atmosphere is measured. A complete curve of the OTF is also needed for the separation of the various causes of spot broadening and wander. Complete details of the data processing are given in the theses of Crager (5) and Connor (6). Copies of these two theses are being supplied under separate cover.

To measure the OTF, a single TV image field is first transferred to the Quantex DS-30 from the video disc. A background field is then transferred from the video disc. This is subtracted from the image field in the DS-30. The background is ordinarily very small as the image has been taken through a narrow-band interference filter matched to the laser source wavelength.

After subtraction, in the DS-30, of a complete background field from a complete image field that includes an image of the point laser source, a single raster line at a time is transferred to the hp-9825 calculator. The line transferred is limited in

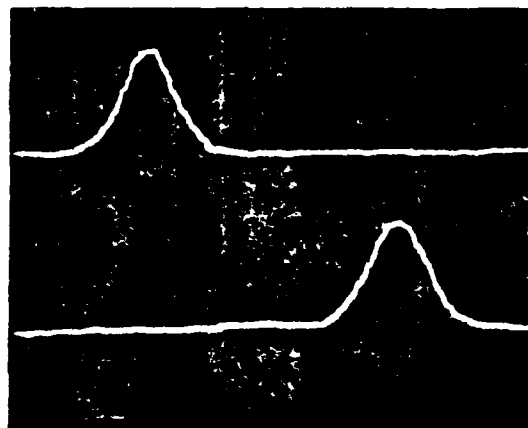


Fig. 2a. Signals for the image of a point source for the TV line passing through the image center.
Top trace: Direct signal from Vidicon
Bottom trace: Signal after recording in tape recorder, disc recorder, DS-30 digitizer and recorder, digital to analog conversion for viewing.

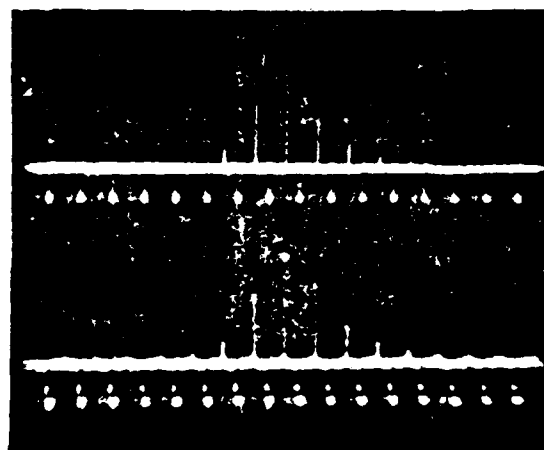


Fig. 2 b. Signals for the image of a point source for a sequence of TV lines covering the image. The envelope of these peaks is processed to give image profile.
Top trace: Direct signal from Vidicon
Bottom trace: Signal after recording in tape recorder, disc recorder, DS-30 digitizer and recorder, digital to analog conversion for viewing.

length to about twice the number of pixels required to express the image shape - usually 20 to 50 pixels. The line signal is then summed in the hp-9825. This sum corresponds to the integrated light passing through the slit of a slit scanner. Successive lines are then summed similarly and the sequence of sums becomes the "line-spread function". This corresponds to the signal function obtained by a slit scanner. This line-spread function is stored in the hp-9825 memory. The next field is then analyzed similarly. To obtain the "long-term" line-spread function, successive line-spread functions are averaged in the hp-9825.

To obtain the "short-term", or "image-centered line-spread function", the center of area of each line-spread function is calculated and stored in memory. The line center is then shifted to a predetermined position and the average of a number of such centered functions is the image-centered line-spread function. The RMS average of the center displacements needed to center is the RMS "image-wander" value. Its square is the variance of the wander.

Next, the Fourier transforms of the two line-spread functions are carried out in the hp-9825. Each of these is then divided point-by-point by the transform of the line-spread function of the imaging telescope, in the absence of turbulence. This removes the effects of the instrument. The result is two curves of the OTF of the atmosphere, the line-term, and the image-centered, OTF values. The curves can be plotted out when desired. Next the OTF curves are fitted to the Fried model to yield C_n^2 . Ordinarily, the two values of C_n^2 are identical, if the image motion is due to turbulence alone, and the turbulence is not unusual. The RMS wander displacement also yields a value of C_n^2 .

Determination of the values of C_n^2 is not actually needed for much of the work to be carried out here, but that value is a convenient single number that characterizes the level of atmospheric turbulence along the optical path. The actual shape of the line-spread functions will be what is used in the data processing to separate the various types of line spread. For the wander, the actual values of the variance are also the values that will be used in the separation of various wander causes.

Data Processing for the Designator Spot Pattern

The details of this data reduction also appear in references (5) and (6). Before discussion of the data analysis a few features of the equipment operation need to be mentioned. It would be desirable for the timing of the TV field initiation to be synchronized with the designator flash occurrence, in order to have the flash occur during the TV blanking and flyback. If the designator flash occurs randomly relative to the vidicon, it could occur during the period in which the electron beam is scanning the area of the image. This would make the data processing much less dependable. In practice an occasional TV field would be lost. Synchronization would make every flash useful.

The image of the designator spot taken by the close-up vidicon is next analyzed. Basically, the same data processing procedure is used as to obtain the OTF of the atmosphere. The TV image is digitized and the background subtracted in the DS-30. The average of a number of images is obtained, both the image-centered average, and the uncentered average. The process of obtaining the image-centered average also yields the variance of the image wander.

The image-centered line spread function is the convolution of the actual spread of the designator and the spread due to the atmosphere. To separate the two spreads, the Fourier transform is taken off the image-centered line spread function. This is then divided, point-by-point by the Fourier transform of the atmospheric line spread function (the OTF of the atmosphere). The resulting function is then reinverted to obtain the spread due to the designator alone. This is plotted out on the plotter. This curve is one of the primary goals of the measurement. This can be used, then, as the information needed to correct errors in the optics of the laser designator system.

The variance of the image wander, obtained above, is the result of both the actual wander of the designator beam and the atmospheric wander. The two can be easily unfolded, assuming that the statistics are reasonably Gaussian. The atmospheric wander of the designator, due to internal instability, would also be Gaussian. The variance of the combined wander is then simply the sum of the wanders of the atmosphere and the designator. Hence the atmospheric wander variance is simply subtracted from the observed total wander variance, to obtain the wander of the designator. This also is one of the primary goals of the measurement as this information can help in the readjustment of the laser and optics to reduce the wander.

Analysis of the pattern projected on a uniform target has been demonstrated in work at the Naval Postgraduate School, using a pulsed GaAs laser source. The images have been digitized, subtracted from background, and the spot profile processed to yield a line-spread function, as well as a spot wander value. These have then been separated from the atmospheric spread and wander.

2.3b TV VERSUS LINE-SCANNER COMPARISON

Direct comparison of OTF values from the NPS mechanical line-scanner with those from the TV system was accomplished by use of a beam splitter in the output optics of a 270 inch focal length Cassegrain telescope. The two images analyzed were thus identical. The telescope viewed a point (HeNe) laser source at the far end of a tunnel, 132 meters in length. Turbulence in the tunnel was produced by overhead heat duct ports and amounted to moderate turbulence.

The video signals from the TV system were recorded with the system proposed here for field use. The recorded signals were analyzed later by the techniques previously described in this report, with the output in the form of a plotted curve of OTF as a function of angular spatial frequency.

The NPS mechanical line-scanner signals were recorded on a Precision Data frequency modulated tape recorder, with a recording band-width of 100 kHz. This recorder is frequently used for this purpose with the NPS line scanner, although recently the online data processor has made this recorder unnecessary. In this case it made careful processing possible for identically the same time interval as that used for the TV data.

A pair of curves of OTF are shown in Figures 3a and 3b for the NPS line scanner and the TV systems, respectively. The data is for the long-term average. The output of the NPS line scanner yields the actual data points as well as the best-fit curve from the Fried model.(4) The output of the TV system displayed only the best-fit Fried curve, at the time of that data reduction. In the future it will also display the actual data points. The two OTF curves can differ only in their horizontal scale, because they are curves for the same model. A customary measure for comparison is the angular spatial frequency at which the OTF has decreased to a fraction, $1/e$, of its initial value of unity. This point is often used as a measure of the coherence "length". For the NPS scanner, the $1/e$ point occurs at 26.7 lines per milliradian. For the TV system, the $1/e$ point occurs at 29.6 lines per milliradian.

The above values are in agreement within approximately 10%. This corresponds to an agreement within 10% for C_n or within 20% for C_n^2 . This degree of agreement indicates that the TV system is adequate to replace the mechanical line scanner for measurements of the OTF. That agreement is quite good, and since much of the use of the two TV systems for OTF involves use of the results of one system in terms of the other, the matched pair of two TV systems should reduce the effects of systematic error.

LONG TERM OTF
 TIME - 1
 WAVELENGTH - 0.6328 MICROMETERS
 RANGE - 132 METERS
 DIAMETER OF OPTICS - 0.2032 METERS
 CN - 3.65E-07 CNSQ - 1.33E-13

NPS LINE-SCANNER

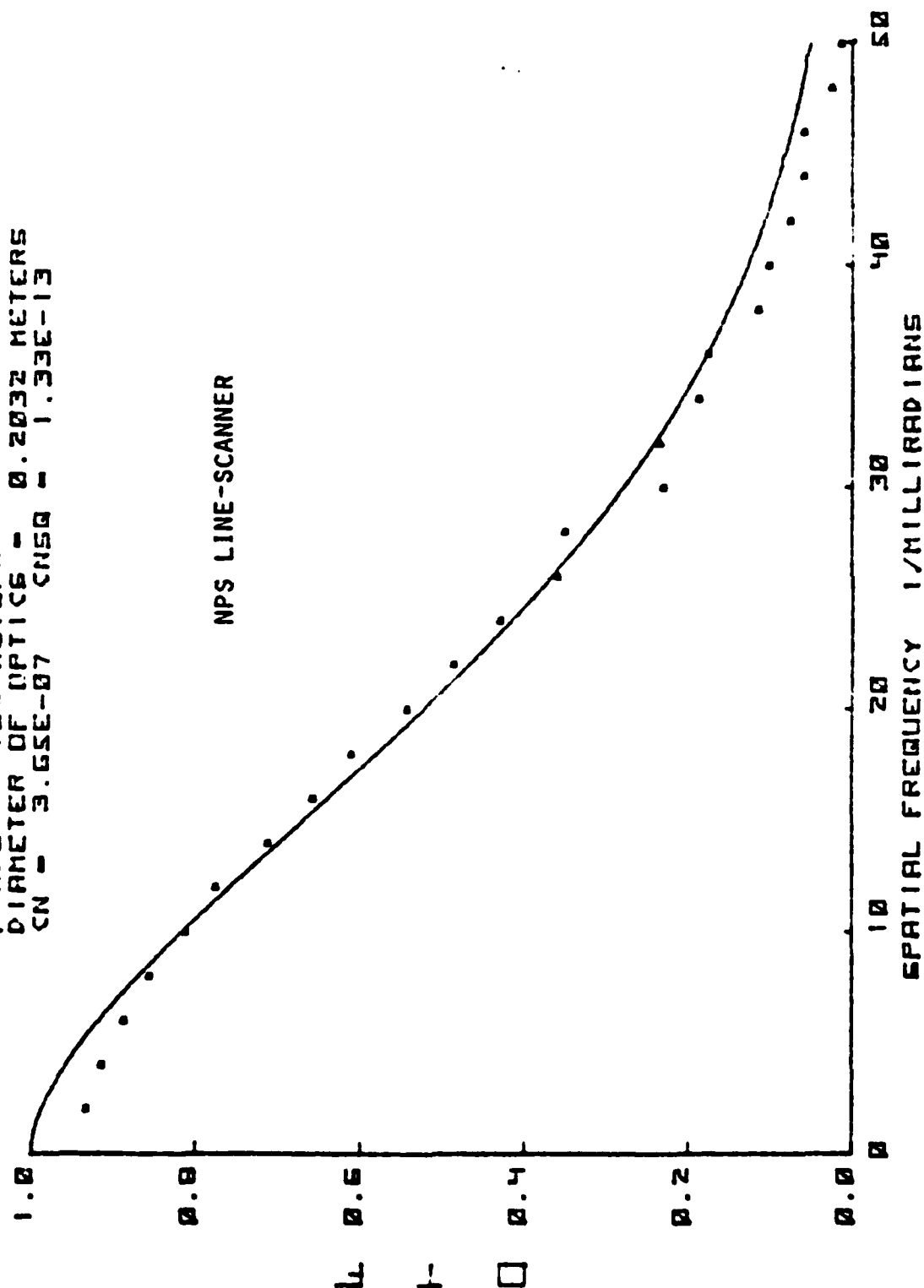


FIG. 3A. OTF OF THE ATMOSPHERE

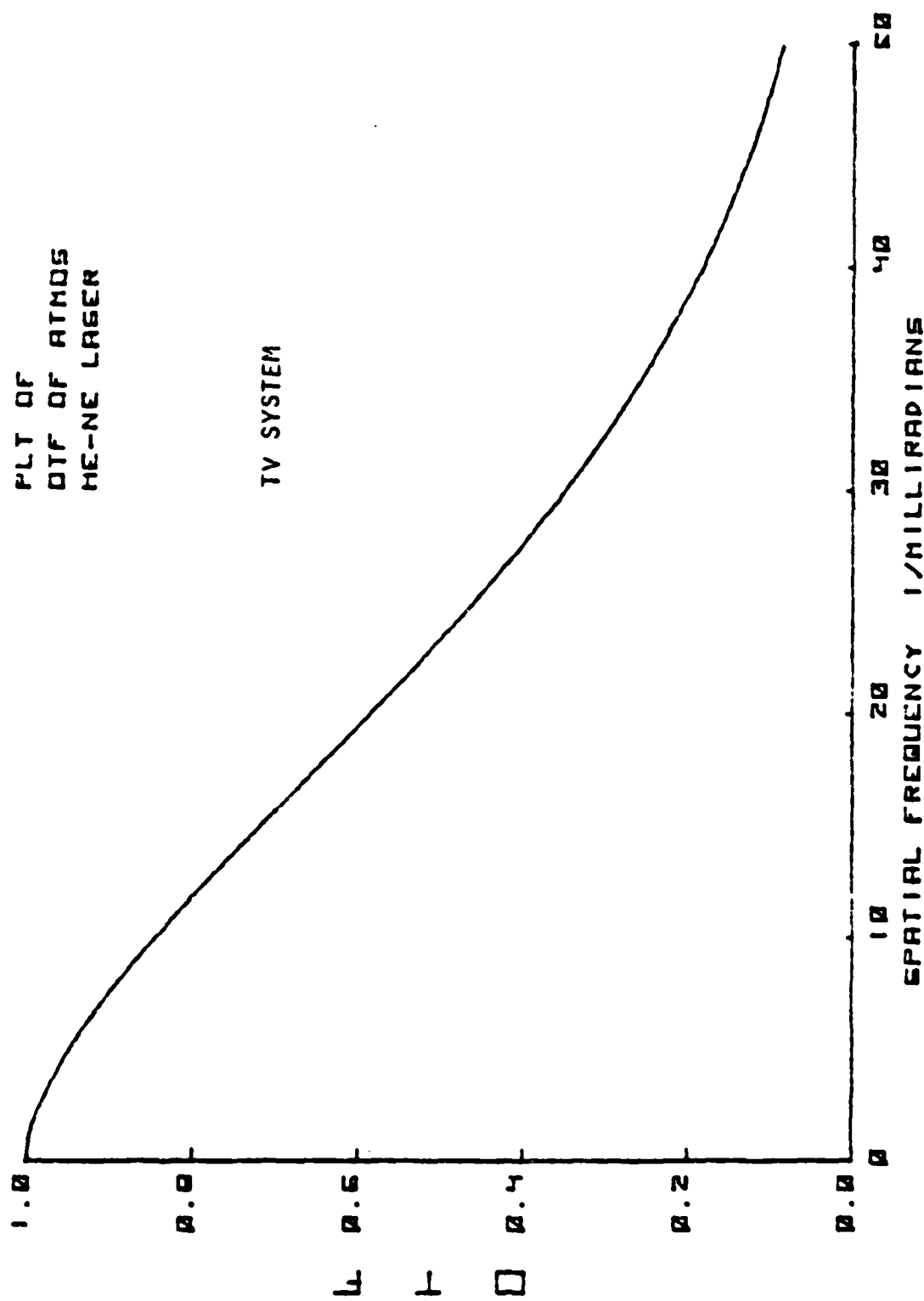


FIG. 38. OTF OF THE ATMOSPHERE

SECTION 3. APPENDICES

3.A PROPOSED FIELD TEST PROGRAM

3.A.1 Introduction

The proposed test program has three general phases. In the first phase, a uniform reflectivity target screen would be used. These techniques would be adapted in the second phase to permit use of a real target such as a tank. The techniques utilized in the first two phases would be chosen so that they are adaptable to a third possible phase in which real targets would be in motion.

3.A.2 Phase One, Uniform Targets

In the first phase of the program, field measurements would be made with a target screen with uniform reflectivity, at a representative range. The equipment is planned to be arranged as shown in Figure 4. The measurements and data reduction would be carried out in three successive steps.

a) Step One

In the first step, field measurements would be made with a strapped-down laser designator with its spot trained onto a uniform target screen. These measurements would serve to determine the stability of the designator laser and optical system, by separating the atmospheric effects from the overall effects.

The target screen would be viewed with a silicon vidicon located a short distance from the screen along the line between the screen and the designator, but slightly off that line to avoid obscuring the screen from the designator location, as shown in Figure 4.

A silicon focal plane screen is needed for this vidicon in order to reach the 1.06 micrometer, near-IR, wavelength. The usual TV vidicons, or other TV cameras such as orthicons, are optimized for the visual range of wavelengths and do not reach this wavelength.

The close-up vidicon would be equipped with a narrow band-pass optical filter matched to the designator wavelength, to reduce the background signal. The vidicon would view, alternately, the designator spot plus background, and the background alone. The video signals would be tape recorded during tests. Later the signals for the background image would be subtracted from the signals for the background plus designator spot to give the signals for the spot alone. This subtraction would be carried out in a Quantex DS-30 video signal processor.

In addition to the close-up vidicon, another vidicon, with long focal length (telescope) optics, would be located near the designator transmitter and would view a point source laser located in the target screen, as shown in Figure 4. That laser would

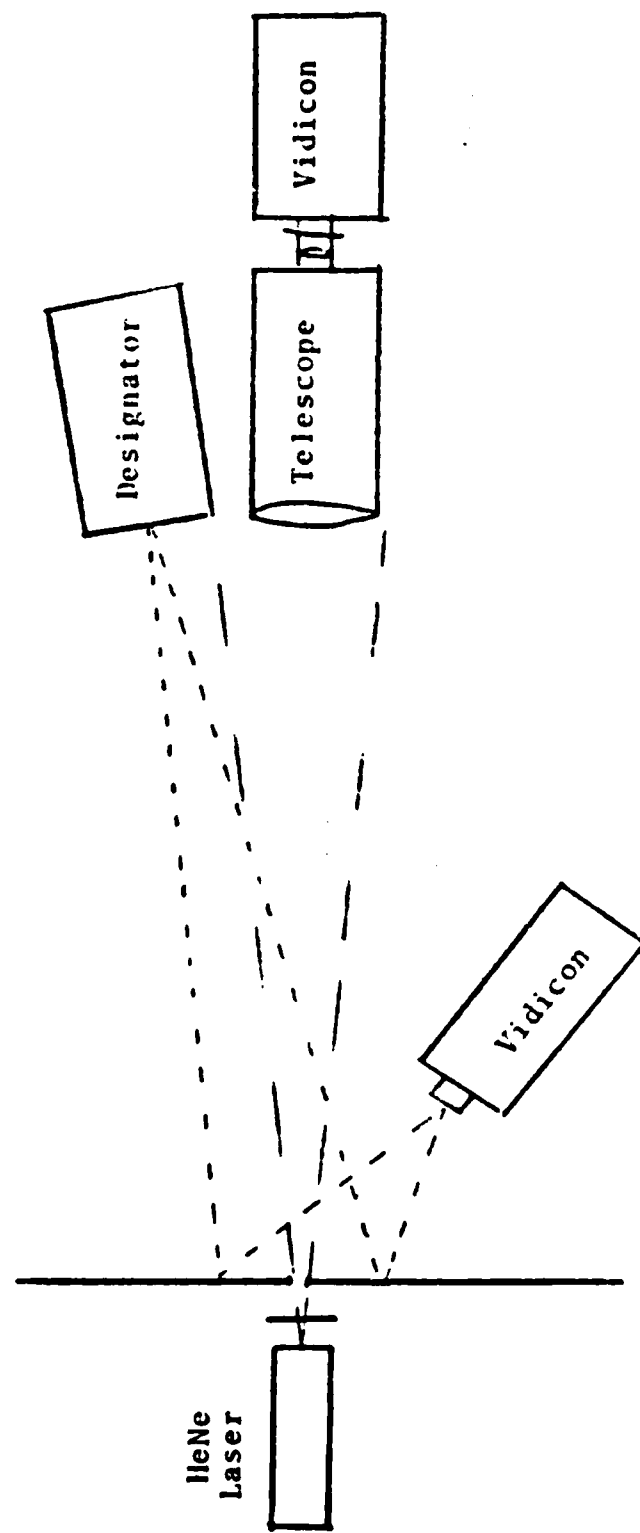


Figure 4. Block diagram of optics

operate at a different wavelength from the designator, e.g. HeNe, at 0.6328 microns. The telescope vidicon would have a narrow band-pass filter to match this laser line. This will eliminate the designator signals, but not completely the daylight continuum background. Separate recording of signal and background will permit subtraction of background here in the same manner as for the close-up vidicon. This vidicon can be a more common visual range vidicon than the silicon vidicon that is required for the 1.06 micron designator signals.

Processing of the taped data from the telescope vidicon would give a quantitative determination of the effects of the atmospheric turbulence. This data would then be used, together with the taped data from the close-up vidicon that views the designator spot on the target screen, to unfold the atmospheric effects from the designator spot width and wander, using Fourier transform techniques. The diffraction spread and any intentional geometrical spread of the designator spot would also be removed. The remaining spread (beam profile) and wander would then be entirely that due to improper laser adjustment, or instability of the laser and associated optics. This data should then make it possible to correct or minimize the defects in the designator system. Even if not corrected, the system would then be characterized, and is ready for use in the next step.

b) Step Two

In the second step, the laser designator would be placed on the unstable platform (mini RPV). The mini RPV would be mounted in as realistic a manner as possible, with engine and all systems running to simulate real operational conditions, particularly with respect to vibration, but with the mini RPV still on a ground based platform. This is necessary, so that the telescope vidicon can be mounted next to it, to view the point source in the target screen and thereby obtain a measurement of the effects of atmospheric turbulence. This would evaluate the actual beam pattern of the designator, as it would be in the air, by removing the atmospheric effects. The beam pattern would now be characterized sufficiently that it can be used in the third step.

c) Step Three

In the third step, the mini RPV would be airborne, directing its laser designator to the uniform target screen. The close-up silicon vidicon would view the screen as before. In this step the distant telescope vidicon viewing the point source, is not necessary, nor could it contribute to the information, if used. It would, of necessity, be ground based and would not look through the same atmospheric path as the beam from the mini RPV to the target. The beam from the designator on the mini RPV is now well enough known that it can be used to evaluate the atmospheric turbulence at the instant of designator firing. The data tape from the close-up vidicon would yield a sequence of beam profiles. The center of each of these is calculated and the profile centered before averaging. The averaged profile, so obtained, is then Fourier processed to remove the known designator profile, that has been determined in step two, above. From this reduced profile,

the atmospheric turbulence is determined. Knowing this turbulence, the expected wander of the spot center is calculated. This is then unfolded from the directly measured spot wander to give the motion of the spot due to the platform motion alone.

All of the above general processes have been proven by application in a slightly different situation, namely determining the optical properties of lasers transmitted from shipboard. A new feature in the present experiments is the use of vidicons for imaging. Scanning slit telescopes have been used previously to carry out the same type of measurements. In the results reported in this report, data reduction for imaging with vidicons, has now been tested in laboratory work at the Naval Postgraduate School.

3.A.3 Phase Two, Nonuniform Targets

In the second phase of the program, field measurements, similar to those in phase one, would be carried out, but with nonuniform reflectivity targets, such as a tank with natural landscape as background.

The measurements would differ from those of phase one in that an additional laser, with the same wavelength as the designator, would be used to provide pulse illumination of the target, from a close-up location. This pulsed illumination would alternate with the designator pulses. The close-up vidicon would view the scene under pulse illumination plus background light, and then under background light alone. Both signals would be tape-recorded. Later the two images would be subtracted to yield the signals for illumination by laser light alone. The close-up vidicon would then view the scene when the designator spot is pulsed. This again would be tape recorded. The difference of this scene and the background would be used later for the signals for the designator alone. Later in data reduction, the designator spot signals would be divided pixel-by-pixel by the signals for uniform laser illumination. This process normalizes the spot profile to be the same as if it had reflected from a uniform reflectivity target.

Steps One, Two and Three, above would then be carried out, after the normalization, to analyze the behavior of the laser and platform.

3.A.4 Phase Three, Future Moving Targets

The systems for use in phases one and two would be set up so as to be extendable to laser designator analysis for moving targets. This will involve all the techniques of phases one and two, including steps one, two and three, plus provision of background laser illumination by flashes that follow, or lead, the designator pulses as closely as possible. In practice this means following or leading by one TV field time interval. This is 1/60 second for standard American TV. Use of a more rapid scan TV system would improve the situation. However, the normalization operation would be improved by a lateral shift of the uniform illumination

calibration image, to more exactly coincide with the image at the time of the designator flash. The proper displacement could be determined by carrying out a correlation of the two images as a function of offset, with the final offset determined by the maximum correlation between the images. This would be a time-consuming operation if both lateral and vertical offset were involved. If the direction of offset is known, for example for a vehicle that is constrained to move on a road surface of known inclination, then the correlation operation would be greatly reduced. Carrying out this type of measurement seems well within the capability of the equipment to be provided for phases one and two, except that a larger computer will probably be needed. This should be borne in mind in selecting the computer for use in phases one and two.

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